NPS-EC-05-001

NAVAL POSTGRADUATE SCHOOL

SIGNAL POPULATION IN THE LICENSE-EXEMPT WIRELESS-RADIO BANDS at the MOUT SITE

by

Wilbur R. Vincent, Richard W. Adler, and Andrew A. Parker

October 2004

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

NAVAL POSTGRADUATE SCHOOL
Monterey, CA 93943-5000

RDML Patrick W. Dunne, USN President	Richard Elster Provost

This report was prepared for the CDTEMS Field Experiment Program. Any opinions, findings, and conclusions or recommendations expressed in this document are those of the authors and do not necessarily reflect the views of the United States Government.

This report was prepared by:

Wilbur R. Vincent Research Associate Professor	Richard W. Adler Research Associate Professor

Andrew A. Parker
Research Associate

Reviewed by:

Jeffrey Knorr Chairman, Department of Electrical and Computer Engineering	Leonard Ferrari Associate Provost and Dean of Research

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 2004	Technical Report

4. TITLE AND SUBTITLE Signal Population in the License-Exempt Wireless-Radio Bands at the MOUT Site

5. FUNDING NUMBERS

6. AUTHOR(S)
Wilbur R Vincent; Richard W. Adler, and Andrew A. Parker

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Signal Enhancement Laboratory
Department of Electrical and Computer Engineering
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER
NPS-EC-05-001

SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
CDTEMS Field Experiment Program

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the authors and do not reflect the official policy or position of the Department of Defense, or other U.S. Government agency.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT
The radio-signal and radio-noise population at the MOUT site was examined in portions of the radio spectrum of interest. Measurements of the ambient signal population were made as well as the increased signal population during the conduct of a training exercise. In addition supplementary measurements of the signal population were obtained at the CIRPAS Hangar location.

14. SUBJECT TERMS
Radio interference, radio noise

15. NUMBER OF PAGES
35

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFI- CATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500 **Standard Form 298 (Rev. 2-89)**
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

LIST OF FIGURES

1. INTRODUCTION

The radio-signal population and radio-interference conditions were examined in portions of the radio spectrum at the Military Operations in Urban Terrain (MOUT) site located at the former Fort Ord, California on two occasions. Background measurements were made on 18 August 2004, and measurements were made during a field exercise on 30 September 2004. The purpose of the measurements was to identify any signal or noise that might interfere with radio communications and data links during field exercises, and to observe the occupancy of portions of the radio spectrum of interest during a field exercise.

Additional measurements of the occupancy of the bands of interest were made at the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) Hangar located at the Marina, CA (OAR) airport. These additional measurements were made at the completion of the MOUT exercise.

Available instrumentation was installed in a NPS instrumentation van for mobility, and it was used for the measurements. The instrumentation is briefly described in Section 2. Extensive information about the occupancy and use of portions of the radio spectrum is provided in the form of photographs of time-history views of signals and noise in selected portions of the radio spectrum. All examples of data included in this report are calibrated in frequency, time, and amplitude.

Figure 1 shows a photograph of the instrumentation van at the MOUT site.

Figure 1 Photograph of Instrumentation Van at the MOUT Site

2. INSTRUMENTATION

A Naval Postgraduate School instrumentation van was equipped with radio spectrum measurement equipment, and it was used for this effort. Figure 2 shows a photograph of the instrumentation van and its diesel generator trailer at a field measurement location. The van could be rapidly moved from location to location, and it could be operated while in motion.

Figure 2 Photograph of Instrumentation Van

Antennas for each band of interest were installed in the roof of the van. Figure 3 shows the three antennas used for these measurements. Short coaxial cables ran from each antenna through the roof vent and to instrumentation preamplifiers located directly below the roof vent.

Figure 3 Photograph of Antennas on the Instrumentation Van

Two sets of instrumentation were installed in the van. One set covered the band from 0.1 MHz up to 1250 MHz. The second set covered the frequency range of 10 MHz up to 14 GHz. Figure 4 is a photograph of the 10-MHz to 14-GHz instrumentation. A Hewlett Packard Model 3565A Spectrum Analyzer is on the bottom of the photograph, the time-history display in the middle of the photograph, and preamplifiers are on the top of the time-history display.

Figure 4 Instrumentation for the UHF and Microwave Bands

Figure 5 is a photograph of the instrumentation used to cover the 0.1 to 1250 MHz frequency range as well as the digital oscilloscope camera used to photograph data and the laptop computer used to store data files. A Hewlett Packard Model 141 Spectrum Analyzer is shown on the lower left part of the photograph. The time-history display used to observe signals in the 0.1- to 1250-MHz band is above the spectrum analyzer, and its preamplifier and a filter are located on top of the display.

Figure 5 Instrumentation for the 0.1- to 1250-MHz Band

The oscilloscope camera and the laptop computer shown in Figure 4 were shared with the first instrumentation suite to minimize equipment and allow all files to be stored on one computer.

3. AMBIENT MEASUREMENTS

3.1 General Approach

The background electromagnetic environment in the license-exempt wireless-radio bands was explored at the MOUT site prior to the conduct of a field exercise. This was conducted on 18 August 2004. The purpose of the effort was to obtain information about ambient signals at that site that might interfere with the operation of devices in these bands during an extensive field exercise to be conducted at a later date. In addition to the exploration of the ambient environment, an 802.11b access point and one portable communications set was briefly operated to obtain preliminary information about its spectral and temporal properties.

The instrumentation van and its diesel-generator trailer were driven to the MOUT site on 18 August 2004. The van was parked near the middle of the MOUT facility and operated for several hours collecting data on emissions in the wireless-radio bands.

The MOUT facility is located in a remote part of the former field-exercise range of Fort Ord, California, now under the control of the United States Bureau of Land Management. The facility is located at the bottom of a valley with rather steep hills surrounding the valley. No visible sign of facilities or equipment for the use of the license-exempt wireless-radio bands were apparent to the van's operators during the test other than a single test communication device. This device was under the complete control of a NPS student.

Since the location of the van was in a valley surrounded by high hills, the ambient population of signals in the bands of interest was expected to be very low to none. Of interest was that earlier measurements at nearby higher elevation locations had identified two rather strong emissions in the 2.4-GHz license-exempt wireless-radio band. The two emissions originated from a nearby mountaintop communications site that provided wireless communications to clients in nearby urban areas. These two emissions were found at higher elevations in the hills surrounding the MOUT site and on the road to the site, but not at the actual test location. Signal attenuation due to terrain loss reduced the level of these signals well below the noise floor of the instrumentation and below the detection levels of the communications systems used for the tests as long as the communications systems were deployed at the lower elevations of the MOUT site.

3.2 Ambient Results

Figure 6 shows that the band is almost vacant of emissions at the low level of the MOUT site. A very low-level signal (or set of signals) was found near the center of the band. It is suspected that this signal is from a source outside the valley and is attenuated by terrain loss sufficiently that it will not affect the operation of communications systems in this band that are operated at and near the valley floor.

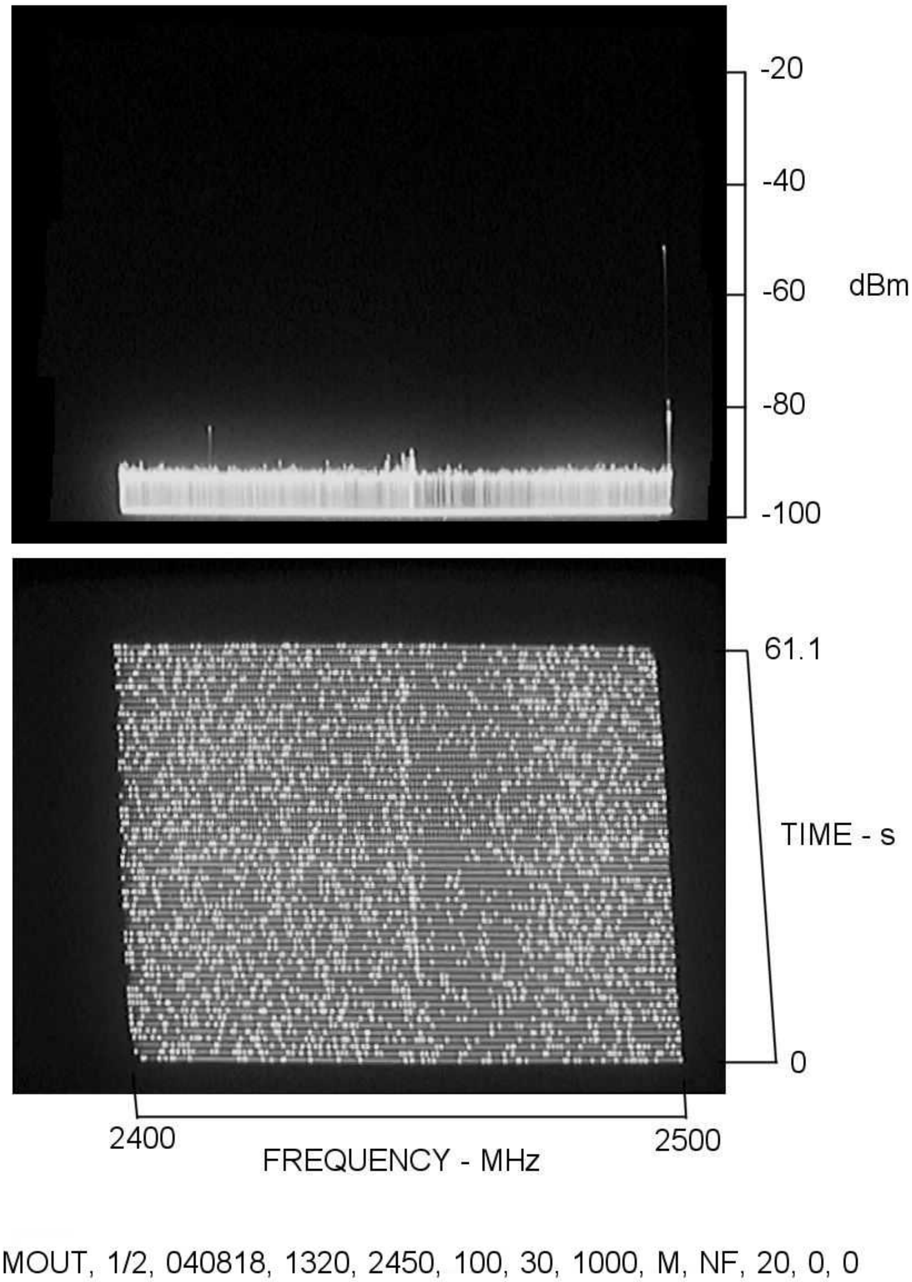
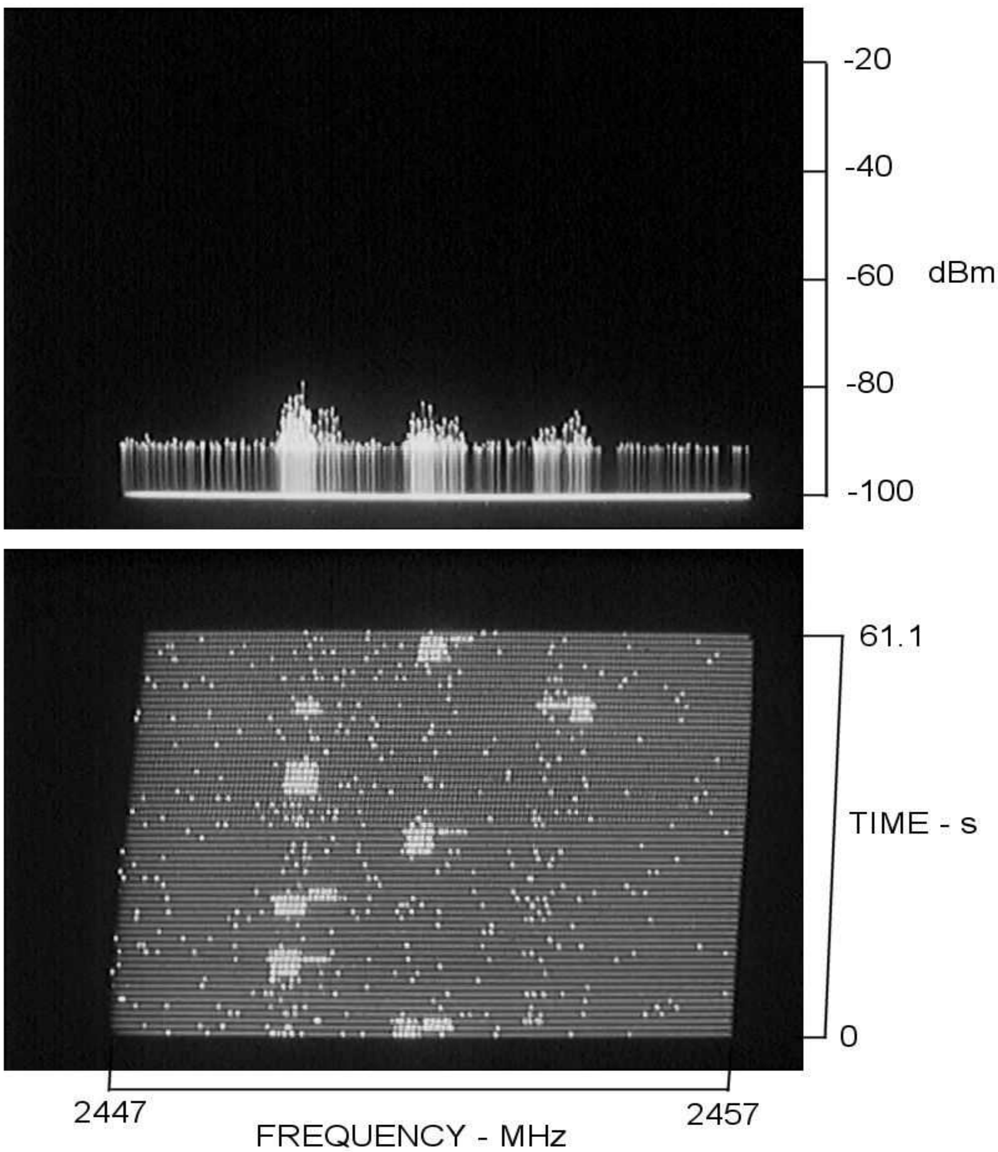


Figure 6 Background Emissions in the 2400- to 2500-MHz Band

The frequency axis was changed from a width of 100 MHz to 10 MHz to obtain a more detailed look at the low-level signals shown in the prior example. Figure 7 shows that pairs of bursts of signals are on three frequency channels. Again, these signals are low in amplitude and should not interfere with the operation of other devices in the lower elevations of the valley.

The source of the signal bursts was not identified during the ambient background measurements. Of interest is that these signals were not found during other measurements at higher elevation locations in the general vicinity of the MOUT site.



MOUT, 9/10, 040818, 1340, 2452, 10, 100, 1000, M, NF, 20, 0, 0

Figure 7 Pairs of Low-Level Burst Signals

During the ambient measurements at the MOUT site, one communications unit of the type to be used in later field exercises at the site was available for test transmissions. It was set up about 100 ft from the NPS instrumentation and operated for a few minutes. Figure 8 shows the emission from the unit at turn-on. At turn on spurious emissions were noted above and below the normal operating frequency of the unit. A normal spectral shape occurred a few seconds later, but a few intermittent pulses higher than the normal emission bandwidth were noted about ¾ the way down the time axis.

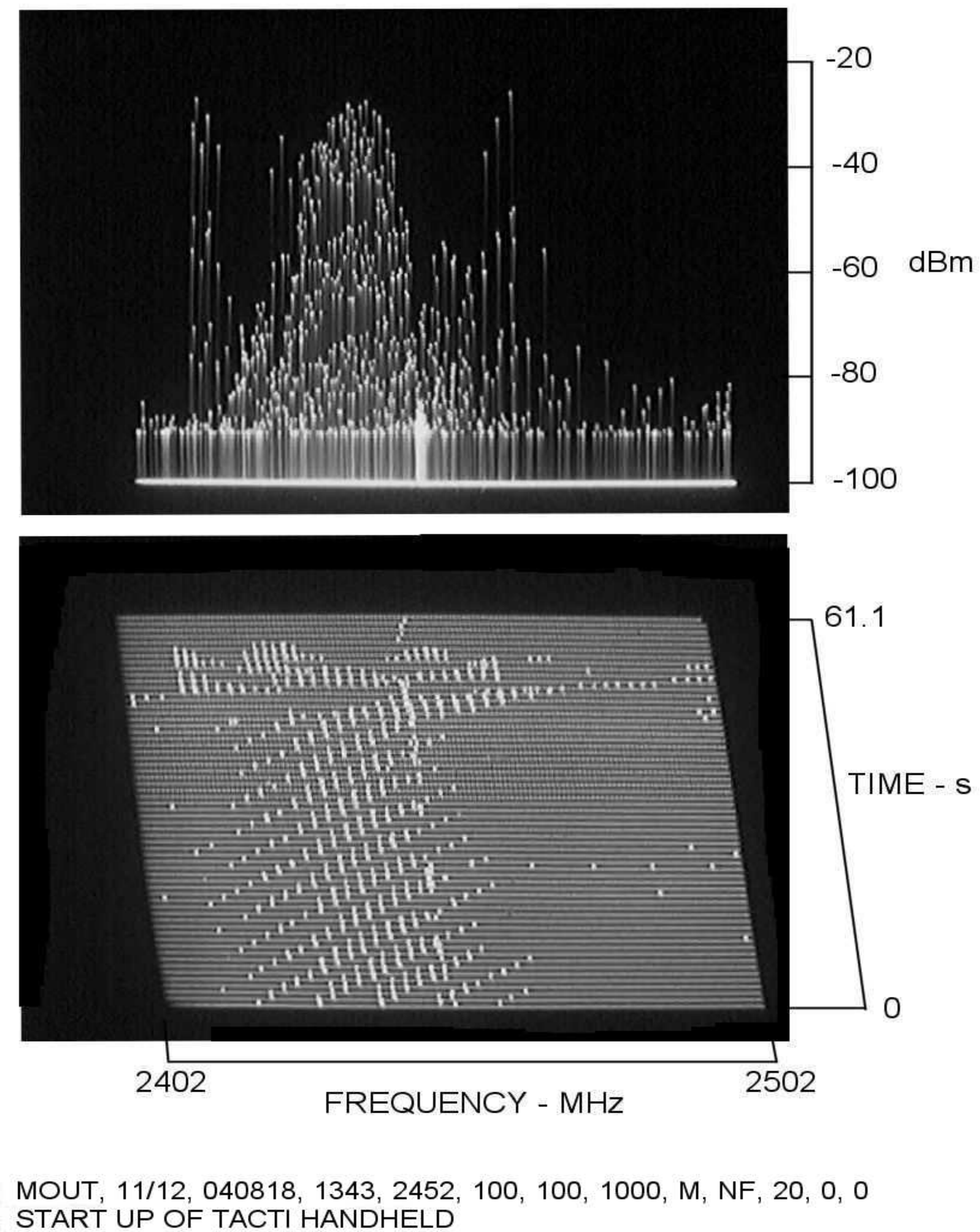


Figure 8 Spectral Content of Test Communications Device, Example 1

The time-history view in Figure 8 is also somewhat confusing since it is not representative of the temporal structure of a signal from an 802.11b device. The structure changes later and became more representative of an emission from an 802.11b device as shown in Figure 9. Of interest is that spurious pulse emissions above and below the normal spectral width of the signal were still present. This suggests the unit needs to be checked for proper operation.

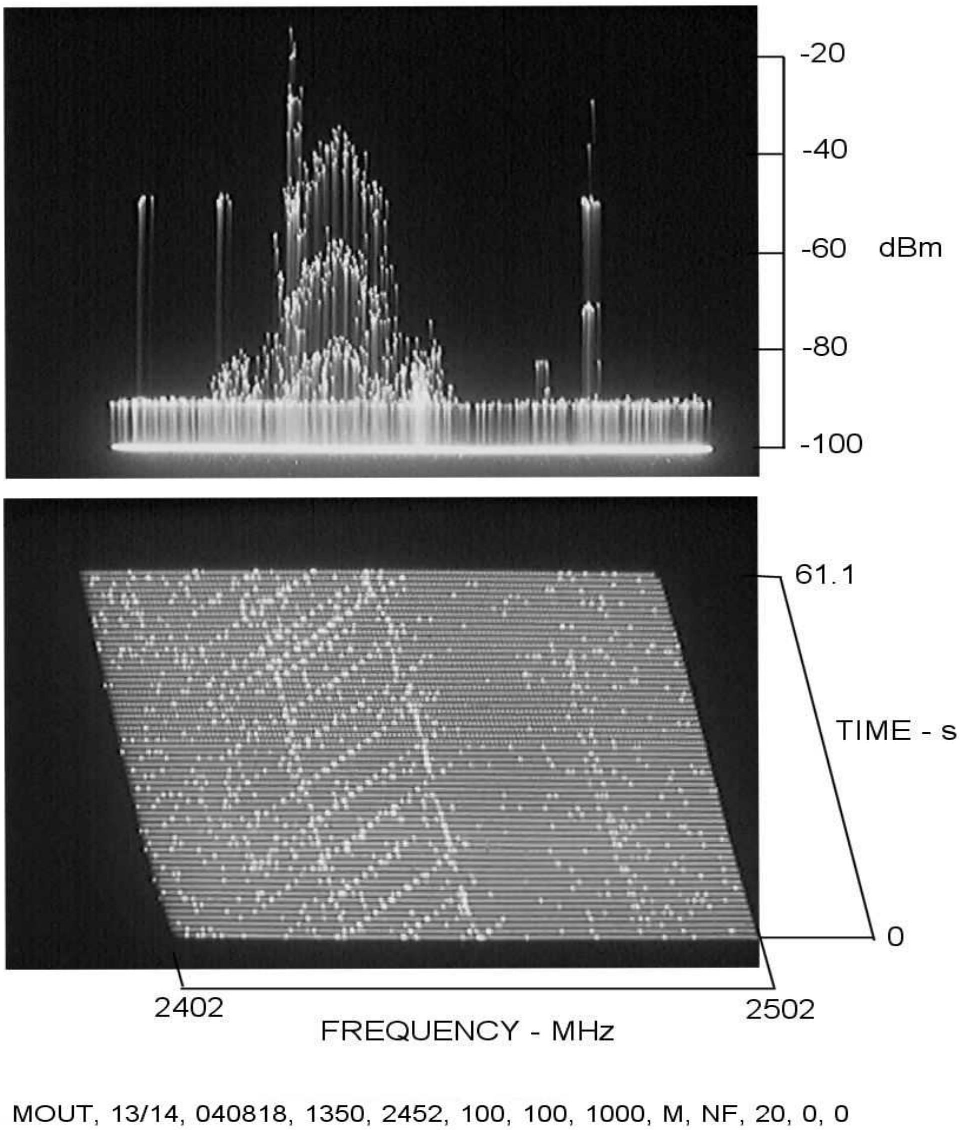


Figure 9 Spectral Content of Test Communications Device, Example 2

Low-level signals from the source shown in Figure 7 are present in the above example. These signals were not strong enough to interfere with the operation of the test communications device.

4. FIELD-EXERCISE MEASUREMENTS

4.1 General Approach

The instrumentation van was driven to the MOUT site on 30 August 2004 prior to the start of a field exercise at that location. The van was placed at a convenient location near the center of exercise activity. The occupancy and use of four portions of the radio spectrum were examined prior to, during, and after the exercise.

The three bands observed covered the frequency ranges of 600 to 800 MHz, 890 to 940 MHz, 2400 to 2500 MHz, and 5400 to 5800 MHz. One instrument operator controlled the 0.1- to 1250-MHz instrumentation suite and time-shared it for measurements on the two lower-frequency bands. A second operator controlled the 10-MHz to 14-GHz instrumentation suite and time-shared it for measurements on the two upper-frequency bands. In this case it was necessary to change the antennas and preamplifiers for each band change. The sharing of instrumentation limited the simultaneous measurement to any of the two bands.

At the end of the MOUT exercise, the van was driven to the CIRPAS hangar located at the Marina Airport (OAR) for additional measurements of emissions at that location.

4.2 Occupancy and Use of the 2.4-GHz Band

Figure 10 shows the occupancy and use of the radio spectrum from 2400 to 2500 MHz at the start of the field exercise. Multiple 802.11b-type emissions were noted at this time including emissions from at least seven different access points along with occasional replies from hand-held devices, especially at the highest-frequency access points.

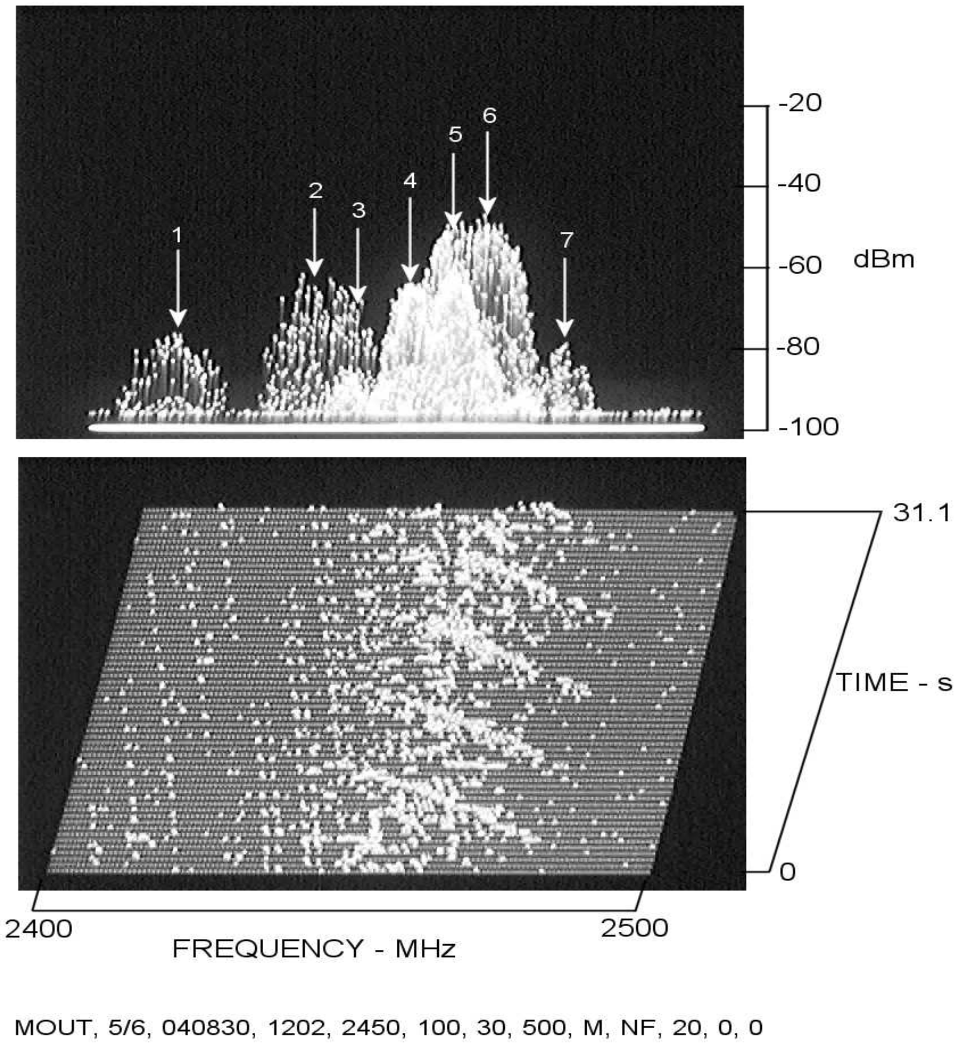


Figure 10 Occupancy of 2400- to 2500-MHz Band, Example 1

The top view shows the amplitude of each signal in dBm at the input terminals of the instrumentation preamplifier (essentially the power received by the intercept antenna and delivered to a 50-Ohm load). The spectral width and shape of each signal is shown in this view. An arrow is placed at the center frequency of each emission and an emission identification number is located above each arrow.

Emission 1 is at the low-frequency end of the 2400- to 2483.5-MHz license-exempt band. This emission is in the clear and does not interfere with any other emission and the other emissions do not interfere with this signal. Emission 2 is higher in frequency. Emission 3 is the small bright area on the upper-frequency side of Emission 2 at an amplitude of about –83 dBm. These two signals interfere with each other. Emissions 4, 5 and 6 overlap and interfere with each other. Emission 6 appears to be from a non 802.11b device. Emission 7 appears to be partly free from interference, but its spectral width overlaps that of Emission 6 at locations close to Emission 6.

The bottom view is a time-history view of signals over a 31.1-second period. This view consists of 60 successive scans of the spectrum analyzer where the newest scan is at the bottom and the oldest scan at the top. The data in this view is the same as that for the amplitude-vs.-frequency view except that the amplitude is severely compressed. The frequency axis under the time-history view is also used for the upper view.

The slanting lines in the time-history view are the result of interaction between the repetitive, wide-bandwidth, synchronizing-pulses of the access points and the scanning process of the spectrum analyzer. The scan time of the spectrum analyzer must be slower than the period of the synchronizing pulses to show as slanting lines. The somewhat different looking slanting bars associated with Emission 6 are not understood at this time. The other blobs of white between these bars are reply pulses from portable communications gear associated with emissions 4 and 5. No reply pulses were associated with the emissions from access points 1 and 2 at the time of this example.

In this example all emissions are within the 2400- to 2483.5-MHz license-exempt wireless-radio band. All emissions were associated with the exercise underway at the MOUT site. No spurious emission was found at frequencies immediately above or below this band.

To better understand the overlapping emissions from the access points and the portable communications devices, a smaller 50-MHz wide portion of the band from 2432- to 2452-MHz is shown in Figure 11. The signals are identified with the same numbers used in the previous example.

Emissions 2 and 3 remain about the same as for the previous example. The synchronizing lines for Emission 2 are clearly shown in the time-history view, but the threshold was raised sufficiently to eliminate the synchronizing lines from the weaker Emission 3. Emissions 4 and 5 are shown in the upper view along with pulses at higher amplitudes. The lower view shows the synchronization pulses from Emissions 4 and 5 along with data pulses from portable communications devices. The lack of a clean spectral shape of the emissions from the portable communications devices is puzzling since the reply pulses should fall on top of, and have the same shape as, the access-point pulses. In addition, the overlapping spectral shapes of Emissions 4 and 5 clearly show they interfere with each other.

Spurious pulses from some emitter are shown above the emission from Access Point 7.

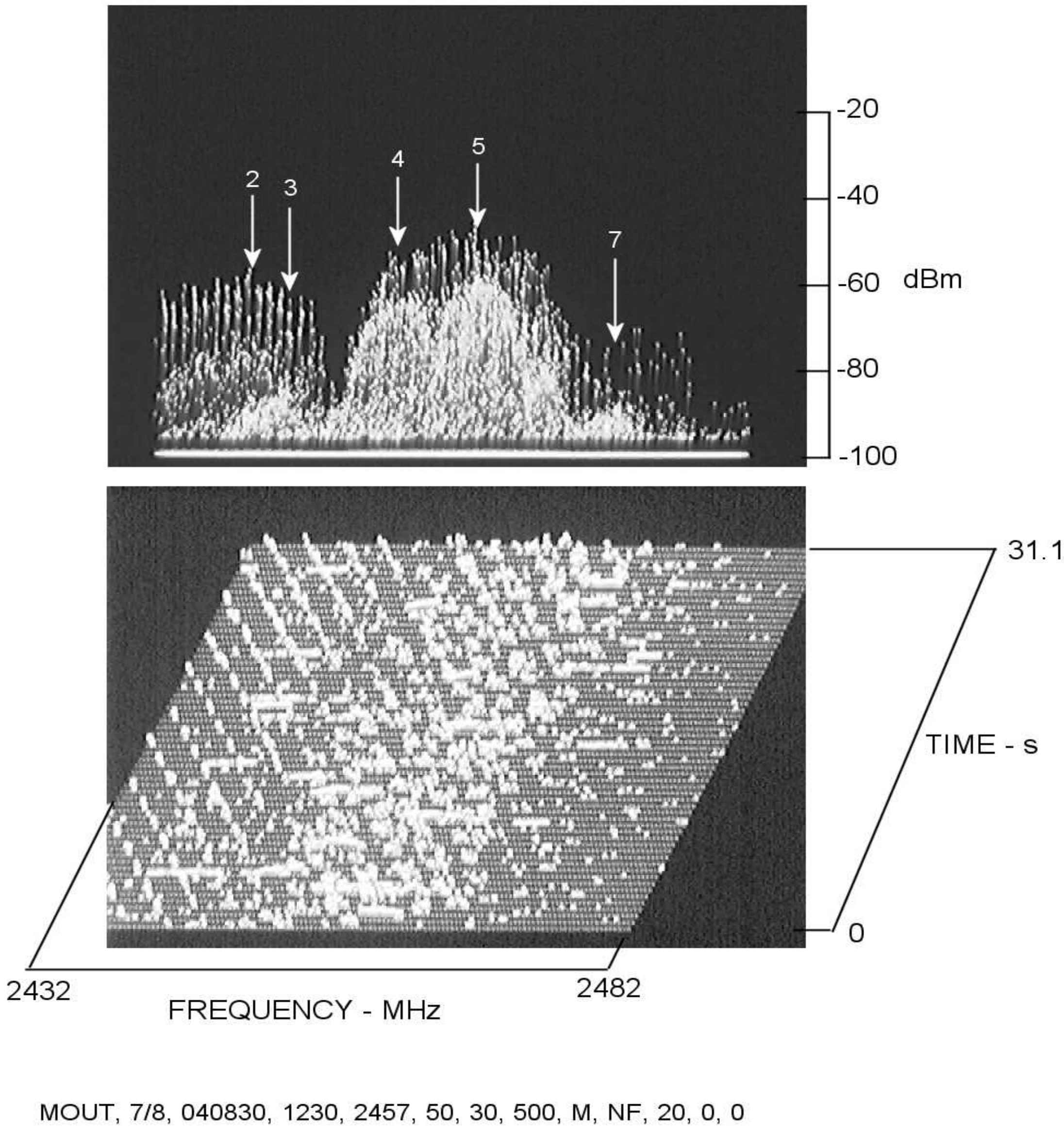


Figure 11 Occupancy of the 2432- to 2452-MHz Band

The occupancy of the 2400- to 2500-MHz band generally increased as the exercise activity continued and fell off at the end of the exercise. Figure 12 shows the occupancy of the band at the height of the activity. It is obvious that all of the access points and the portable communication units moved closer to the instrumentation van. The longer duration of the time axis resulted in more dense amplitude-vs.-frequency spectral information. Source 1 remained free of interference. Sources 2 and 3 appear to be buried under emissions from nearby portable communications units. Sources 4 and 5 now are about equal in amplitude and also are lower in amplitude than signals from portable communications devices. Source 7 is higher in amplitude than in the earlier data.

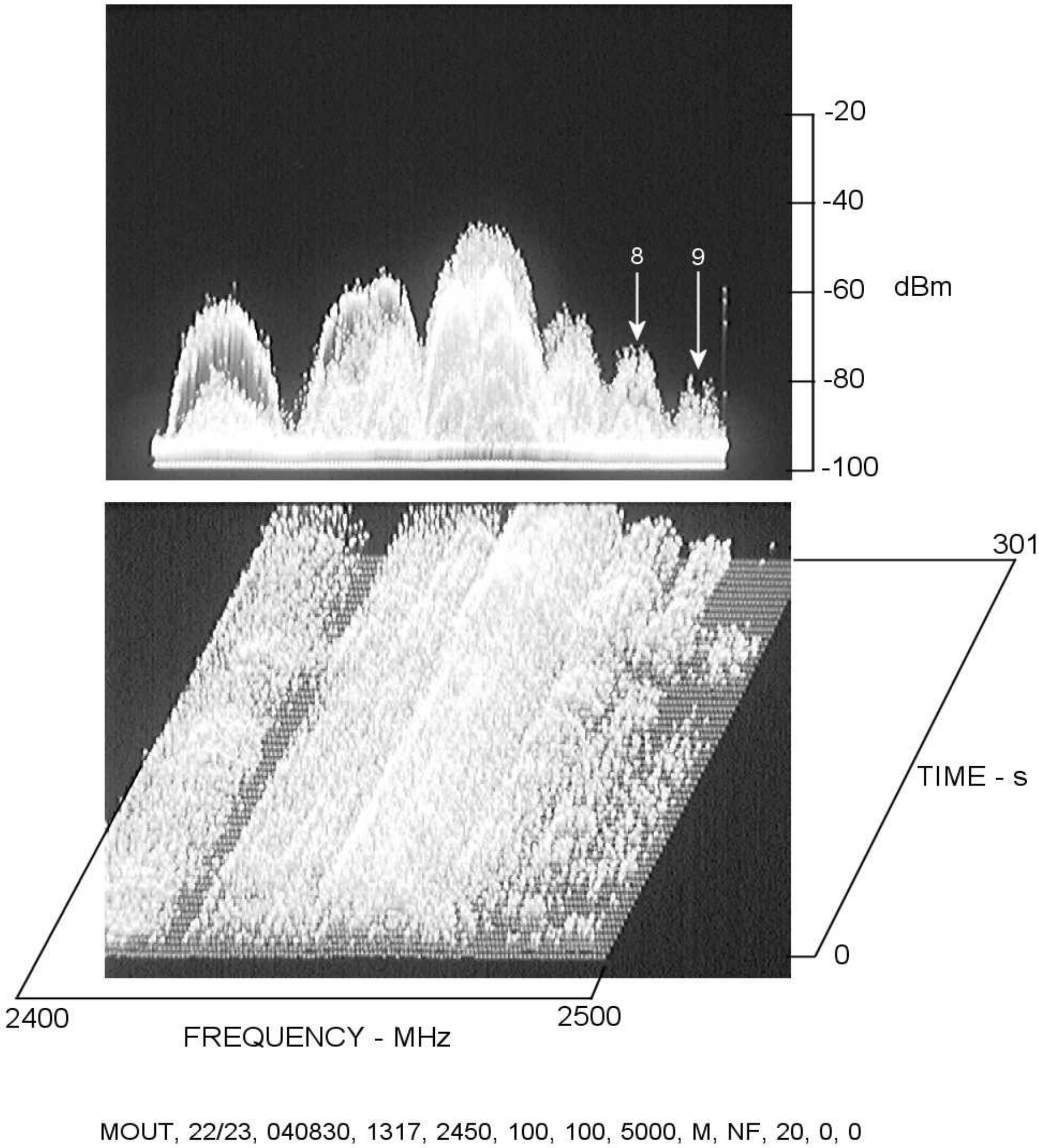


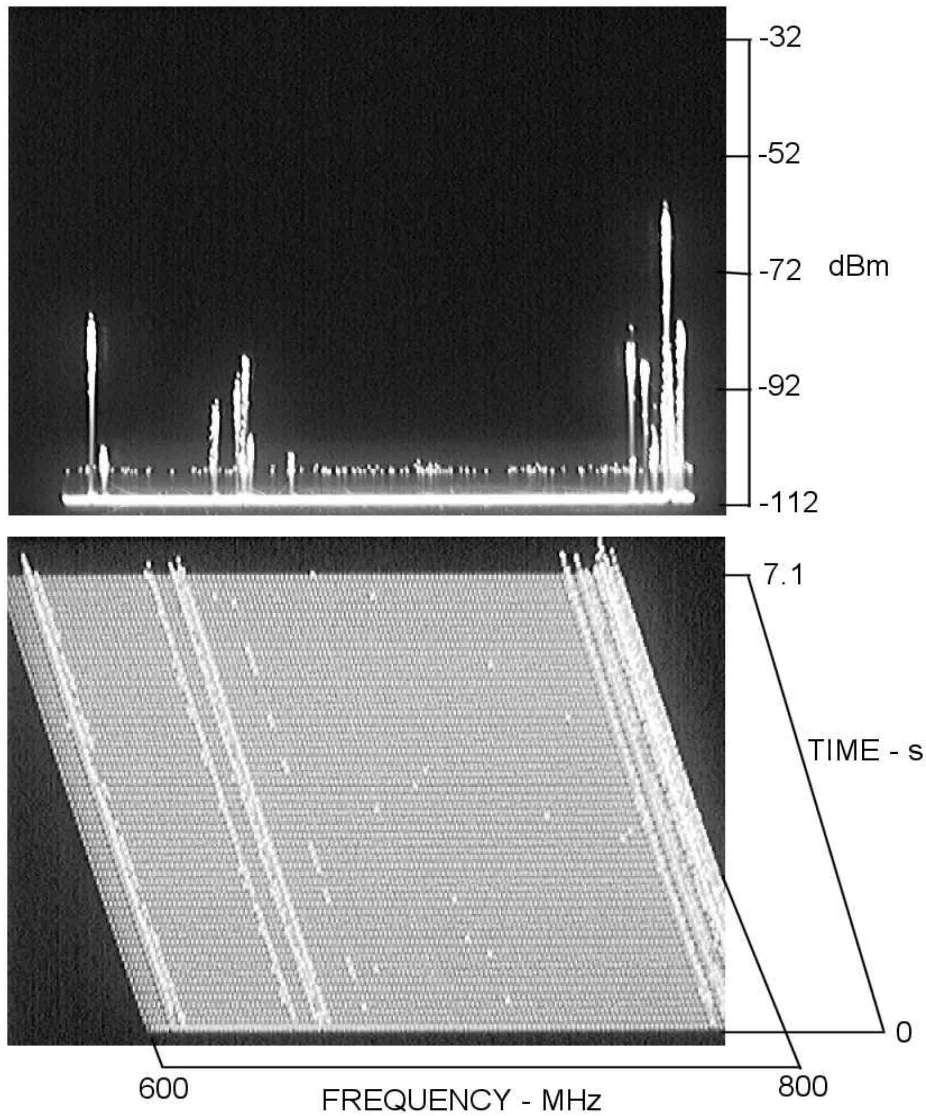
Figure 12 Occupancy of the 2400- to 2500-MHz Band, Example 2

Two new sources appear in Figure 12. They are labeled sources 8 and 9. Both are above the limits of the 2400- to 2483.5-MHz license-exempt band, but they are within the limits of the wider Industrial, Scientific, and Medical band of 2400 to 2500 MHz and the same band limits provided to radio amateurs. These two new sources were associated with the exercise.

Shortly after the data in Figure 12 was obtained the entire band became vacant which coincided with the end of the exercise.

4.3 Occupancy and Use of the 600- to 800-MHz Band

Some related activities use portions of the radio spectrum near 700 MHz. This part of the spectrum was monitored during the exercise to determine if other signals might interfere with normal operations of the related activities. Figure 13 shows the occupancy of that portion of the spectrum at the height of the exercise.



MOUT, 18/19, 040830, 1308, 700, 200, 30, 100, M, NF, 22, 0, -10

Figure 13 Occupancy and Use of the 600- to 800-MHz Band

No significant or unknown signal appeared in this portion of the spectrum that would interfere with the conduct of the exercise.

4.4 Occupancy of the 902- to 928-MHz Band

The band from 902 to 928 MHz is a license-exempt band available for general use. The occupancy of this band was also examined during the height of the field exercise. Figure 14 shows signals in this band along with small additional bands above and below the license-exempt band.

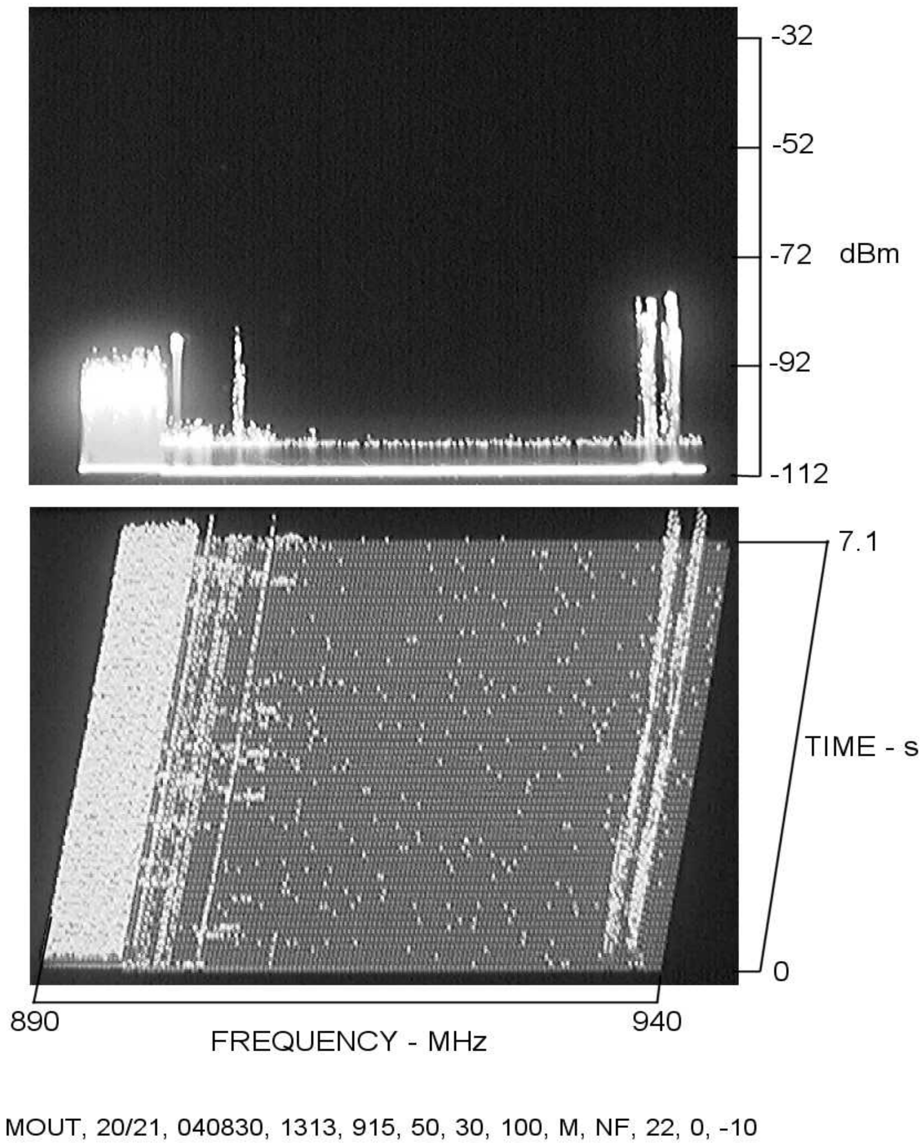


Figure 14 Occupancy of the 890- to 940-MHz Band

No significant signal was found within the limits of the 902- to 928-MHz license-exempt band. Signals shown in Figure 14 above and below this band are from licensed radio services operating mountain-top or tower sites within or near to line of sight of the MOUT location. These services are protected from interference, and their frequencies are not available for general use.

4.5 Supplementary Measurements at the CIRPAS Hangar

At the completion of the exercise at the MOUT site, the instrumentation van was moved to the CIRPAS hangar located at the Marina Airport. Additional ambient measurements were made in the parking lot at the south end of the CIRPAS hangar.

Figure 15 shows signals in the 2400-MHz band during the testing of equipment at that location. All signals observed are believed to originate from devices under test at the CIRPAS hangar. Multiple 802.11b type emissions were found as well as non-802.11b emissions. The highest level pulses appear to be from a frequency-hopping emitter that covered the entire band. Pulses from this emitter will occasionally collide with synchronizing and data pulses from 802.11b type emitters, resulting in repeat transmissions and reduced throughputs.

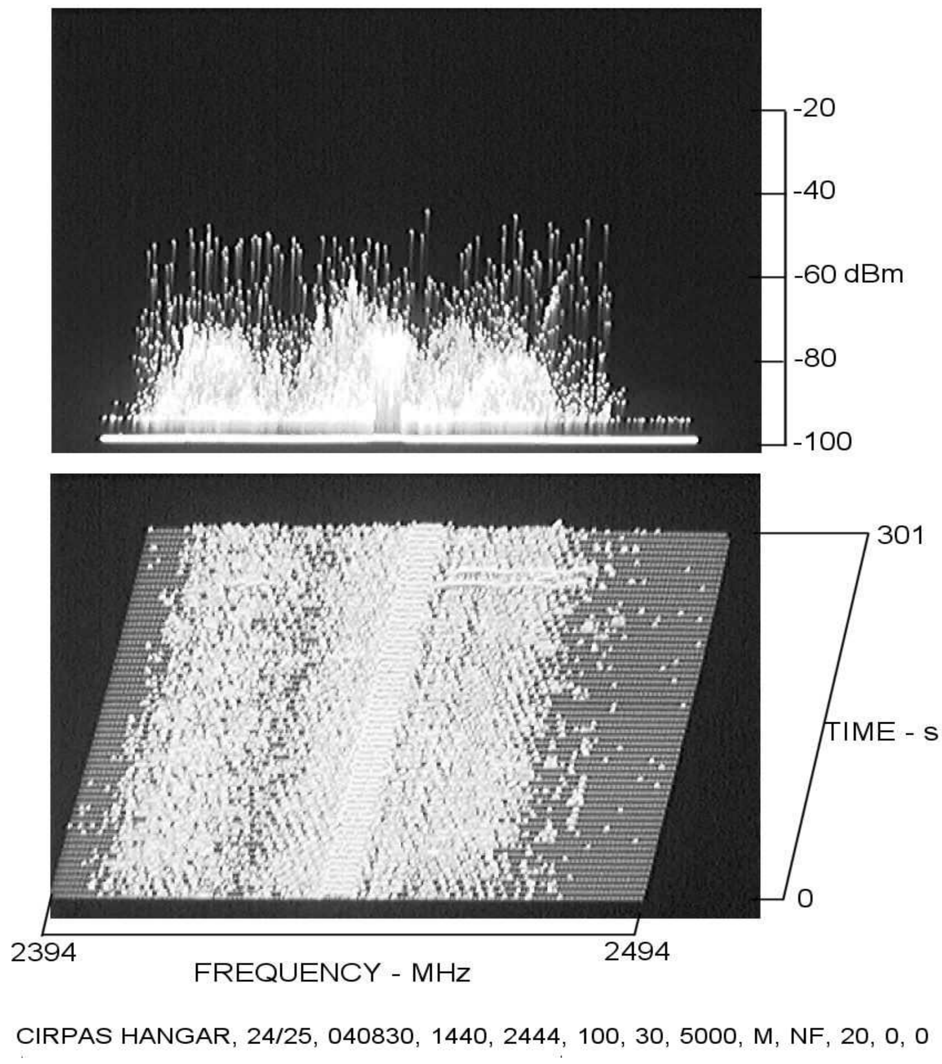


Figure 15 Occupancy of the 2394- to 2494-MHz Band at the CIRPAS Hangar

Initial measurements at the CIRPAS hangar indicated the lack of signals in the 902 to 928-MHz license-exempt band. Multiple wide-bandwidth emitters suddenly turned on while exploring this band.

Figure 16 shows two rather complex broadband signals observed while examining that portion of the band from 912.5 to 917.5 MHz. Two adjacent spread-spectrum emissions appear near the center of the frequency range. These two emissions were present during the entire 64.7 seconds of the measurement time. The complex signal at the upper end of the frequency scale turned off half way down the time axis. It appears to consist of multiple frequency sub-bands but with a common synchronizing-pulse source.

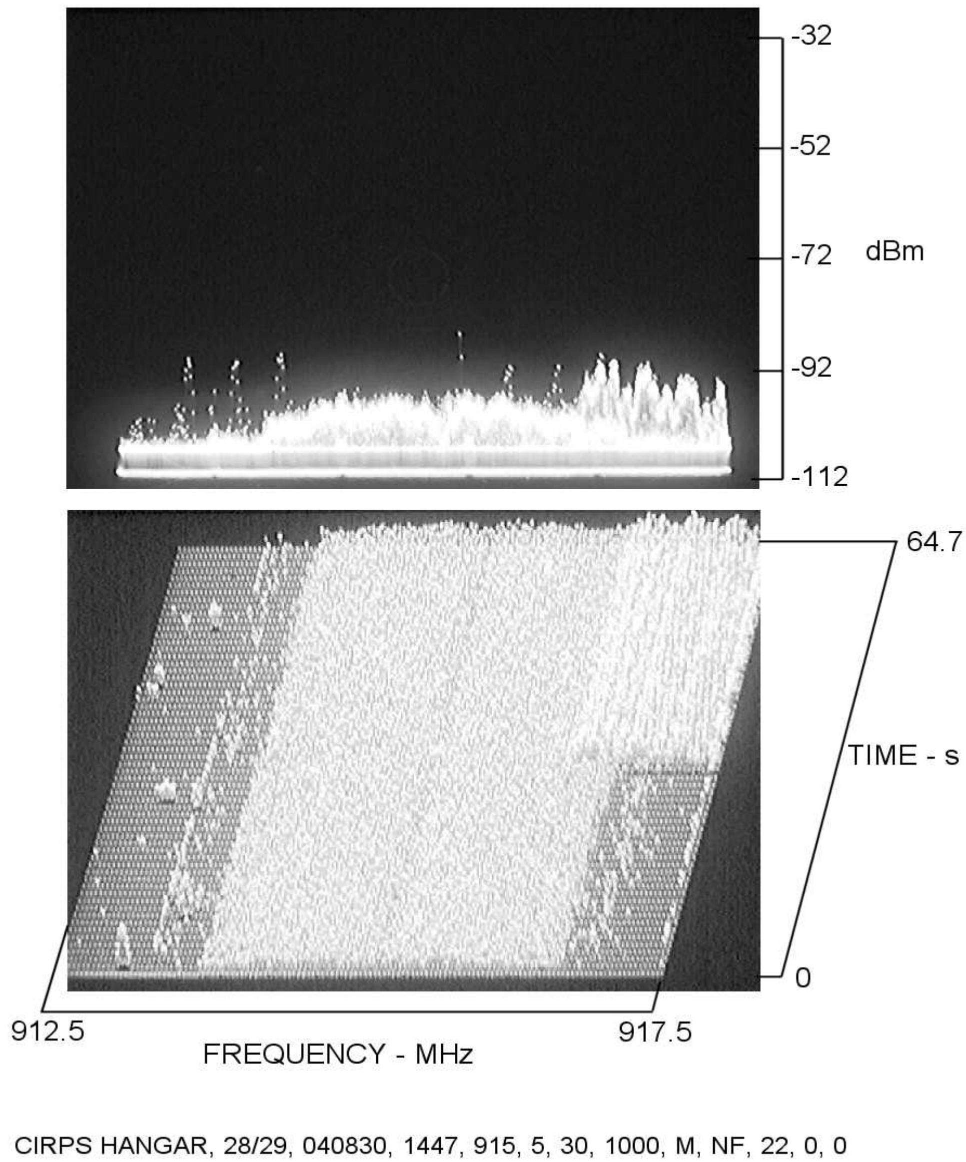
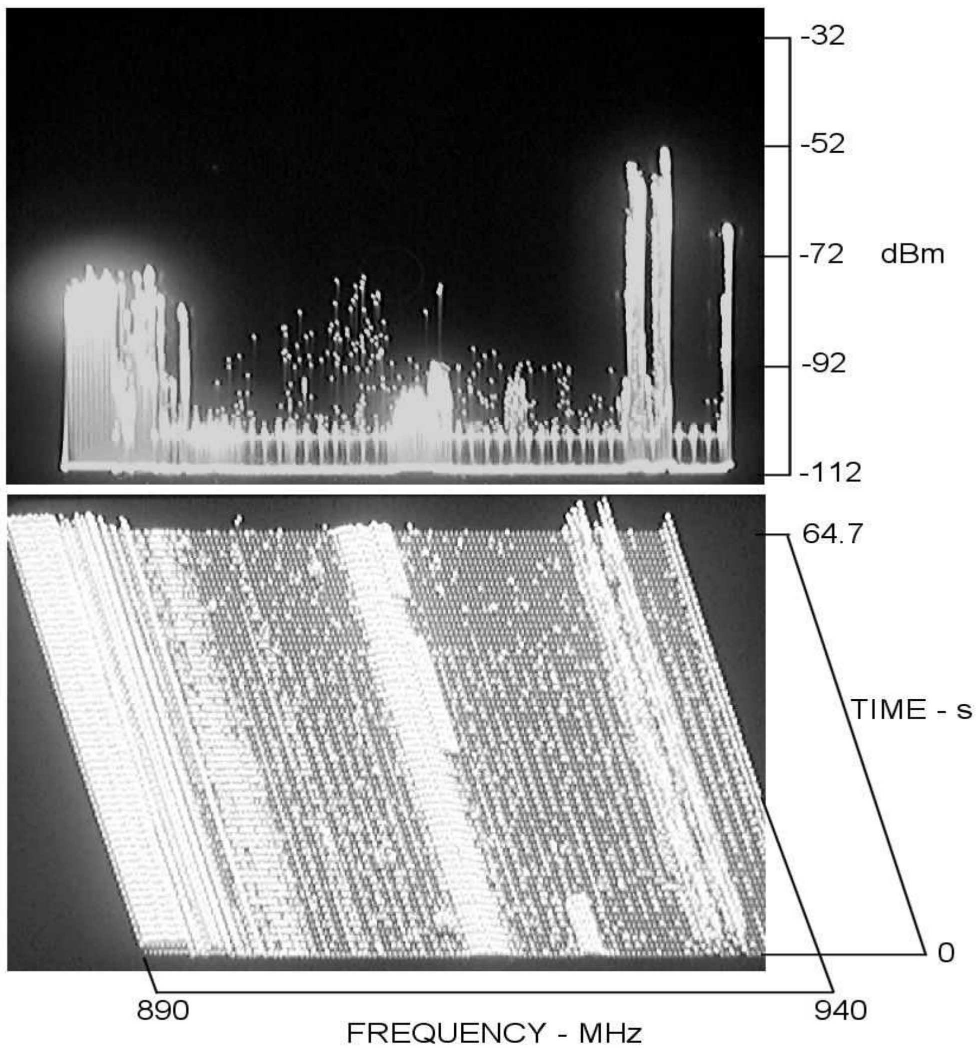


Figure 16 Emissions in the 912.5- to 917.5-MHz Band at the CIRPAS Hangar

Eleven minutes later the entire 902- to 928-MHz license-exempt band was examined and additional signals appeared. Figure 17 shows emissions in the band as well as portions of the spectrum above and below the license-exempt band. The two signals noted in the previous example are near the center of the frequency axis. A brief emission from an unknown source occurred near the bottom of the time axis and at a higher frequency.

The low-level and close-spaced spectral components across the entire frequency axis are unwanted emissions that were traced to radiation from the USB cable connecting the digital camera (used to record data) to a laptop computer. This cable was connected to the laptop about ¼ of the way down the time axis.



CIRPAS HANGAR, 28/29, 040830, 1458, 915, 50, 30, 1000, M, NF, 22, 0, 0

Figure 17 Occupancy of the 880- to 930-MHz Band at the CIRPAS Hangar

4. DISCUSSION

4.1 Ambient Background

Ambient measurement of the wireless-radio bands of interest were made at the MOUT site on 18 August 2004, and they showed only very low-level signals that would not affect the performance of communications systems during a field exercise planned for a later date.

The ambient measurements also included preliminary tests of the spectral and temporal structure of emissions from a test communications device. The test indicated the device emitted spurious pulse signals at start up and at later times. This suggests the communication device and other similar devices should be checked in the laboratory to fully investigate the spurious emission problem.

4.2 Spectrum Use During the Field Exercise

The 2400- to 2483.5-MHz license-exempt band was essentially vacant at the MOUT location prior to the start of the exercise. This condition rapidly changed to a high occupancy of the band at the start and during the entire exercise along with several instances of overlapping signals. No part of the band was free of signals. Signals also appeared in that portion of the spectrum above the license-exempt band from 2483.5 to 2500 MHz. No signal or spurious emission was noted above or below the 2400- to 2500-MHz band.

The data shows that one 801.11b-type signal was free of interference (see signal 1 in Figures 6 and 7), and the communications devices using the access point generating this signal probably performed as expected. All other signals from access points and other sources encountered radio-interference problems. The synchronizing signals from other 802.11b-type access points, and the data signals between the access points and users, indicate these communications systems encountered numerous pulse collisions. This resulted in the retransmission of many blocks of data and a reduced throughput.

The access point equipment appeared to be designed to find free channels or the best channel available. Since free channels were not available, the various communications systems simply piled on top of each other. Since the technical characteristics of the channel-seeking portion of the communications systems were not known, there is no good way to fully assess the extent and impact of the interference on performance from the data collected. A frequency manager may prove useful in planning the communications aspects of the future exercises.

No unusual activity was found at or near 700 MHz. Since the measurements in this report were made under blind conditions and without real-time inputs about exercise progress, no conclusion can be reached about use of this portion of the spectrum by devices associated with the exercise.

The 5.6-GHz license-exempt band was monitored from time to time during the survey. Unfortunately, it was necessary use one spectrum analyzer to examine conditions in both the 2.4-GHz and 5.6-GHz bands. Due to the high level of activity in the 2.4-GHz

band, it received priority for measurement time. No signals were detected in the 5.6-GHz band even though it was known that this band was intermittently used during the exercise. The 5.6-GHz devices were operated some distance from the instrumentation van and on point-to-point links with antennas pointed away from the van. Since only a single nearby point-to-point link was known to be in intermittent operation, and it was operated within the deep valley used for the exercise, no significant interference problem would be expected.

The supplementary measurements at the CIRPAS hangar suggest that similar equipment to that at MOUT was operated at that site. In addition a frequency-hopping signal covered the entire 2400- to 2483.5-MHz wireless-radio band. The signals were lower in amplitude than those encountered at the MOUT site, but a later site inspection showed the large CIRPAS hanger was between the signal sources and the instrumentation van.

Signals were found at the CIRPAS Hangar in the 902- to 928-MHz license-exempt band that may have been associated with the operation of communication or data-transmission devices. These signals are shown in Figures 12 and 13.

Figure 13 also shows low-level radio interference from a portion of the instrumentation system. The USB cable from the digital camera to a laptop computer radiated sufficient noise to be received by the antenna located on the roof of the instrumentation van. The distinctive spectral properties of this low-level interference allowed it to be distinguished from other signals.

No unusual activity was noted at the CIRPAS hangar at and near 700-MHz. The ambient signal population was very low in this portion of the spectrum.

5.0 DATA LOGS FOR MOUT SITE

NPS, MOUT, 0408030, 1of 2 sheets

Location	Pic No.	Date dd/mm/yy	Time Local	Freq. MHz	Span MHz	BW kHz	Scan T ms	Source	Filter id	Preamp dB	RF Attn dB	Ref. dBm	Comments
MOUT	1	040830	1141										Cal-WRV
MOUT	2	040830	1141										Cal- WRV
MOUT	3	040830	1141										Cal-WRV
MOUT	4	040830	1141										Cal-NPS
MOUT	5A	040830	1202	2450	100	30	500	m	nf	20	0	0	Overlapping Signals
MOUT	6T	040830	“	“	“	“	“	“	“	“	“	“	“
MOUT	7A	040830	1230	2457	50	30	500	m	nf	20	0	0	Overlapping Signals
MOUT	8T	040830	“	“	“	“	“	“	“	“	“	“	“
MOUT	9A	040830	1235	2457	20	30	500	m	nf	20	0	0	3 Overlapping Signals
MOUT	10T	040830	“	“	“	“	“	“	“	“	“	“	“
MOUT	11A	040830	1239	2457	20	30	2000	m	nf	20	0	0	3 Overlapping Signals
MOUT	12T	040830	“	“	“	“	“	“	“	“	“	“	“
MOUT	13A	040830	1250	2457	20	100	1000	m	nf	20	0	0	Multiple Overlapping Signals
MOUT	14T	040830	“	“	“	“	“	“	“	“	“	“	“
MOUT	15A	040830	1303	2450	100	100	5000	m	nf	20	0	0	Multiply Overlapping Signals
MOUT	16T	040830	“	“	“	“	“	“	“	“	“	“	
MOUT	17T	040830	“	“	“	“	“	“	“	“	“	“	Display Tweak
MOUT	18T	040830	1308	700	200	30	100	m	nf	22	0	-10	700 Band, No Signals
MOUT	19A	040830	“	“	“	“	“	“	“	“	“	“	“
MOUT	20	040830	1313	915	50	30	100	m	nf	22	0	-10	915 Band, No Signals
MOUT	21	040830	“	“	“	“	“	“	“	“	“	“	“
MOUT	22	040830	1317	2450	100	100	5000	m	nf	20	0	0	Strong Burst, Top of T view
MOUT	23	040830	“	“	“	“	“	“	“	“	“	“	“

NPS, MOUT, 040830, 2 of 2 sheets

Location	Pic No.	Date dd/mm/yy	Time Local	Freq. MHz	Span MHz	BW kHz	Scan T ms	Source	Filter id	Preamp dB	RF Attn dB	Ref. dBm	Comments
CIRPAS	24A	040830	1440	2444	100	30	5000	m	nf	20	0	0	
CIRPAS	25T	040830	“	“	“	“	“	“	“	“	“	“	
CIRPAS	26T	040830	1445	2444	100	30	1000	m	nf	20	0	0	
CIRPAS	27A	040830	“	“	“	“	“	“	“	“	“	“	
CIRPAS	28T	040830	1447	915	5	30	200	m	nf	22	0	-10	
CIRPAS	29A	040830	“	“	“	“	“	“	“	“	“	“	
CIRPAS	30	040830	1458	915	50	30	1000	m	nf	22	0	-10	
CIRPAS	31	040830	“	“	“	“	“	“	“	“	“	“	

INITIAL DISTRIBUTION LIST

	Copies
Defense Technical Information Center 8725 John J. Kingman Rd. Ft. Belvoir, VA 22060-6218	1
Dudley Knox Library, Code 013 Naval Postgraduate School Monterey, CA 93943-5100	2
Research Office, Code 09 Naval Postgraduate School Monterey, CA 93943-5138	1
Federal Communications Commission 445 12th St SW Washington .D.C. 20554 Attention: Julius Knapp, Deputy Chief, Office of Engineering and Technology	1
University of Kansas Center for Research 2385 Irving Hill Road Lawrence, Kansas 66045 Attention: Gary Minden	1
Naval Postgraduate School Electrical and Computer Engineering Department 833 Dyer Road Monterey, CA 93943 Attention: Dr. Richard W. Adler Code EC/ab, Spanagel Hall	1
Naval Postgraduate School Electrical and Computer Engineering Department 833 Dyer Road Monterey, CA 93943 Attention: Mr. Andrew A. Parker Code EC/pk, Spanagel Hall	1

Naval Postgraduate School 1
Electrical and Computer Engineering Department
833 Dyer Road
Monterey, CA 93943
Attention: Mr. Wilbur R. Vincent
Code EC/ra, Spanagel Hall

Mr. George F. Munsch 1
160 County Road 375
San Antonio, TX 78253

USAINSCOM 1
IALO-E
8825 Beulah St
Fort Belvoir, VA 22060-5246
Attention: MS Anne Bilgihan

Mr. Vil Arafilies 1
9542 Westwood Drive
Ellicott City, MD 21042

Reference and Interlibrary Loan Librarian 1
U.S. Department of Commerce
325 Broadway MC5
Boulder, CO 80305
Attention: Ms Carol J. Gocke

Argon ST 1
12701 Fair Lakes Circle
Fairfax, VA 22033
Attention: Mr. Carlo Melnick

Pennsylvania State University 1
Box 30
State College, PA 16804
Attention: Mr. Richard Groff

Mr. Fred Horning 1
Radar Engineers, Inc.
9535 N.E. Colfax St.
Portland, OR 97220

Mr. Werner Graf 1
SRI International
333 Ravenswood Ave.
Menlo Park CA 94025

American Radio Relay League 1
225 Main Street
Newington, CT 06111-1494
Attention: Mr. Ed Hare

Mr. Marvin Loftness 1
115 West 20th St.
Olympia, WA 98501

Professor James K. Breakall 1
Pennsylvania State University
ECE Department
University Park, PA 16802

Mr. J. Mark Major 1
Southwest Research Institute
P.O. Drawer 25801
San Antonio, TX 78228-0510